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Observations on phenology and overwintering of spiders associated with apple and pear orchards in south-central Washington

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Abstract. Beating tray and sweep net samples from apple and pear orchards in south-central Washington State were used to obtain information on life history and phenology of orchard-associated spiders. Cardboard shelters placed in the orchards in the fall and collected during the winter yielded information on spider overwintering. Data were obtained for 43 species in 28 genera and 12 families. The eight most abundant species were *Pelegrina aeneola* (Curtis 1892), *Meioneta fillmorana* (Chamberlin 1919), *Oxyopes scalaris* Hentz 1845, *Theridion neomexicanum* Banks 1901, *Misumenops lepidus* (Thorell 1877), *Xysticus cunctator* Thorell 1877, *Philodromus cespitum* (Walckenaer 1802), and *Sassacus papenhoei* Peckham & Peckham 1895. Each was represented by more than 690 specimens. Salticidae, Philodromidae, and Linyphiidae were represented by the largest number of species. Most species appear to have univoltine life cycles in the study area. Species matured at different times during the season between spring and fall. Twenty-seven species utilized cardboard shelters for overwintering, but some common spiders failed to do so and apparently use alternative locations. Some species overwintered in a broad range of developmental stages, whereas other species overwintered in only one or two instars.

Keywords: Araneae, life history, seasonality

Spiders have been of interest as predators of arthropod pests in orchards for at least 50 years. Chant (1956) found differences between the spider faunas of insecticide treated compared to untreated orchards and listed the natural (i.e., non-orchard) habitats in which many species occurred. Dondale (1956, 1958) recorded 77 species from apple orchards in Nova Scotia, Canada, provided data on abundance, and observed spiders feeding on apple pests. Similar studies were conducted over the next 35 years: Dondale et al. (1979) and Bostanian et al. (1984) in Canada; Specht & Dondale (1960), Legner & Oatman (1964), and McCaffrey & Horsburgh (1980) in the United States; Mansour et al. (1980a) in Israel; Dondale (1966) in Australia; and Hukusima (1961) in Japan. The efficacy of limb tapping for estimating spider populations in apple orchards was investigated by McCaffrey et al. (1984).

Interest in the spider fauna of apple orchards has continued in recent years as pest management programs that rely less heavily on broad-spectrum insecticides are employed with greater frequency, improving the prospects for significant impact by natural enemies on pest control. Studies have examined the tree canopy fauna (Olszak et al. 1992; Wisniewska & Prokopy 1997; Brown et al. 2003; Pekar & Kocourek 2004), the soil surface fauna (Bogya & Marko 1999; Pekar 1999a; Epstein et al. 2000), and the fauna of the herbaceous layer (Pekar 1999b; Bogya et al. 2000; Miliczky et al. 2000). Overwintering spiders (Bogya et al. 2000; Pekar 1999c; Horton et al. 2001) and the bark dwelling fauna (Bogya et al. 1999b) have also received attention. Regional geographic effects were found to be most important in determining the composition of spider assemblages in orchards in different areas (Bogya et al. 1999a).

The phenologies of numerous spider taxa have been documented by field and laboratory studies (Merrett 1967, 1968; Aiken & Coyle 2000; Stiles & Coyle 2001). Annual, biennial, and intermediate length life cycles have been described (Toft 1976, 1978; Wise 1984), and in some cases a species' life cycle has been found to vary within its range, probably influenced by local climatic conditions (Dondale 1961; Putman 1967). Schaefer (1977) distinguished five types of life cycle among spiders from a north temperate region, studied their adaptive strategies for surviving the winter, and noted the importance of the cold season in synchronizing a species' life cycle.

Here we report on spiders that are found in apple and pear orchards in Yakima County, Washington, an important fruit growing area of the state. Life cycles of several common, orchard-associated species are described, and seasonal distribution data for adults and penultimate stage males of less common species are presented. Information on species that utilized artificial shelters for overwintering is also given. Information of this kind may be useful in assessing the potential contribution of spiders to orchard pest control and in scheduling pesticide applications to minimize adverse impact on spiders.

METHODS

Study orchards.—Sampling was conducted in 42 orchards (apple and pear), all of which were located in Yakima County, Washington. All orchards were within a radius of 46 km of the city of Yakima. Some study orchards have been removed from production since completion of the study. The following are latitudes and longitudes for 8 orchards located at the periphery of the study area: 46.4529°N, 120.2292°W; 46.5029°N, 120.1667°W; 46.5835°N, 120.3501°W; 46.5185°N, 120.4235°W; 46.7432°N, 120.7738°W; 46.6618°N, 120.7557°W; 46.4715°N, 120.3834°W; 46.3106°N, 120.1236°W. All other orchards fell within the area demarcated by the peripheral orchards. Insect pest management in the study orchards ranged from conventional programs based on synthetic, broad-spectrum insecticides (e.g., azinphos-methyl) to state-certified organic programs in which use of synthetic insecticides is prohibited. The codling moth *Cydia pomonella* (Linnaeus 1758) is the key pest of apple and pear in this region.

The study was conducted from 1996 to 2001, but not all orchards were sampled each year. Nine apple orchards were sampled in 1996. The following year three pear orchards were sampled in addition to the nine apple blocks. The maximum number of orchards sampled in one year was 19 in 1999. Orchard size was 0.5 to 32 ha.

Sampling.—Arboreal spiders were sampled with a beating tray, 0.45 m^2 in area (Bioquip Products, Gardena, CA). One limb 1–2 m above ground on each of 25 trees (15 trees in 1999) was struck three times with a heavy rubber hose to dislodge spiders. Most specimens were promptly preserved in 70% isopropyl alcohol, but selected specimens were saved and reared (see below). Trees in all parts of an orchard were sampled while walking a winding path. The sampling period usually included April to October. Samples were collected every 1–2 weeks in 1996–1998 and 2000 and monthly in 1999 and 2001. All speeimens taken during this study are held at the Yakima Agricultural Research Laboratory (USDA-ARS) in Wapato, Washington, USA.

Sweep net sampling (net diameter = 38 cm) of the understory vegetation was done in 1996 and 1997 in the same orchards that were monitored with beat trays. An 180° swing of the net constituted a sweep, and 25 sweeps per sample were taken while walking a winding path so as to sample in all parts of the orchard. The sampling periods were late June to late October 1996 and mid-May to mid-October 1997. Samples were taken every 1–2 weeks with longer intervals after an orchard was mowed.

Spiders were also eollected by hand on an irregular basis when chanced upon or during an occasional more serious search. Generally, one or a few specimens of interest were collected. Immatures were reared to obtain a positive identification if necessary. These data were used to supplement beat tray and sweep net data.

Cardboard shelters of two types were used to collect overwintering spiders. The first consisted of a bundle of ten, 12.5 cm × 17.5 cm sheets of cardboard (flute size ~ 4 mm × 5 mm) tied to the lowest crotch of a tree. The second was a 7.6 cm wide strip of cardboard wrapped once around the trunk of a tree 0.5–1.0 m above ground. Shelters were set out in September and October, retrieved in December or January, and stored in a cold room until processed. The number of shelters set out and the number of orchards sampled varied from year to year.

Incidental to a 1998 study of apple bin use by overwintering codling moth larvae, spiders that had also overwintered in the bins were collected. Bins were removed from the field after harvest, held in a cold room at 0.6°–1.7° C until late January, and then placed in a greenhouse at 21°–24° C. Spiders were colleeted as they emerged from the bins.

Sample processing.—Selected specimens were reared for positive identification. They were held in 35 ml plastic cups and provided water and prey of appropriate size weekly. Field captured *Lygus* sp. (Hemiptera: Miridae) and laboratory reared *Drosophila* sp. (Diptera: Drosophilidae) were readily consumed by most species. Onee a familiarity with the local fauna was acquired it was possible to identify a majority of immatures to species. Specimens of definite developmental stage (e.g., penultimate female, antepenultimate male, etc.) mentioned in Results in all cases refer to reared individuals.

Immatures were sorted into small, medium, and large size classes on a species-by-species basis. Since many spiders pass through five to seven nymphal instars, this roughly corresponds to instars one, two, and three for small, four and five for medium, and six and seven for large immatures. Although somewhat arbitrary, this allowed an estimate of the age distribution of immatures through the season. Penultimate males were readily distinguished by their enlarged pedipalps. *Theridion*, *Erigone*, and *Meioneta*, because of their small size, were sorted into a single class of immatures, in addition to penultimate males and adults; antepenultimate male *Erigone* and *Meioneta* were distinguishable based on a slight enlargement of the pedipalps.

Data presentation.—Data from beat tray and sweep net collections were combined to obtain monthly totals. These data are presented graphically for eight abundant species to show the proportion of different developmental stages in each month's collection. Note that a small number of beat tray samples (17) were taken during the first week of November. These data were pooled with the extensive October data for the graphs. Few specimens were taken in November because leaf fall was well underway and spiders had begun a general movement out of the trees. Information for less abundant species is summarized in the Tables which also include data from hand collections when available. Overwintering data from all years were combined.

RESULTS

Salticidae.—Adults of both sexes of *Pelegrina aeneola* (Curtis 1892) were abundant in April, May, and June (Fig. 1). Thereafter males were rare although females were present through October. Females with egg sacs were most common during May and June, but an egg sac containing undispersed first instar nymphs was collected as late as 8 September 2000. A female collected with her egg sac on 3 June 1997 produced a second clutch of eggs in the laboratory. Small immatures were present in all months but comprised over 85% of the population in July. Penultimate males and large nymphs, which included penultimate females, were most abundant in October. Large immatures and penultimate males were the principal overwintering stages although small and medium-sized immatures were well represented (Table 1). Penultimate males were uncommon in the trees during April, but five adults hand-collected in the litter in early April 1997 may indicate that many penultimate males undergo their final molt in this location and then move up into the trees. *Pelegrina aeneola* appears to have an annual life cycle in the study area.

The phenology of *Sassacus papenhoei* Peckham & Peckham 1895 was similar to that of *P. aeneola* but lagged about a month behind (Fig. 1). Adults were most abundant during June, and small immatures dominated the population during August. The few individuals found in overwintering refuges were small and medium-sized immatures (Table 1) as were the few specimens taken in beating tray samples during April. An annual life cycle in the study area is indicated for *S. papenhoei*.

Four species of large jumping spiders in the genus *Phidippus* occurred in the orchards. Collection data, summarized in Table 2, indicates annual life cycles for all four but with different maturation times. The first two or three nymphal instars were very similar in appearance and could not reliably be sorted to species. *Phidippus comatus* Peckham & Peckham 1901 matured during the summer. A female guarding her egg

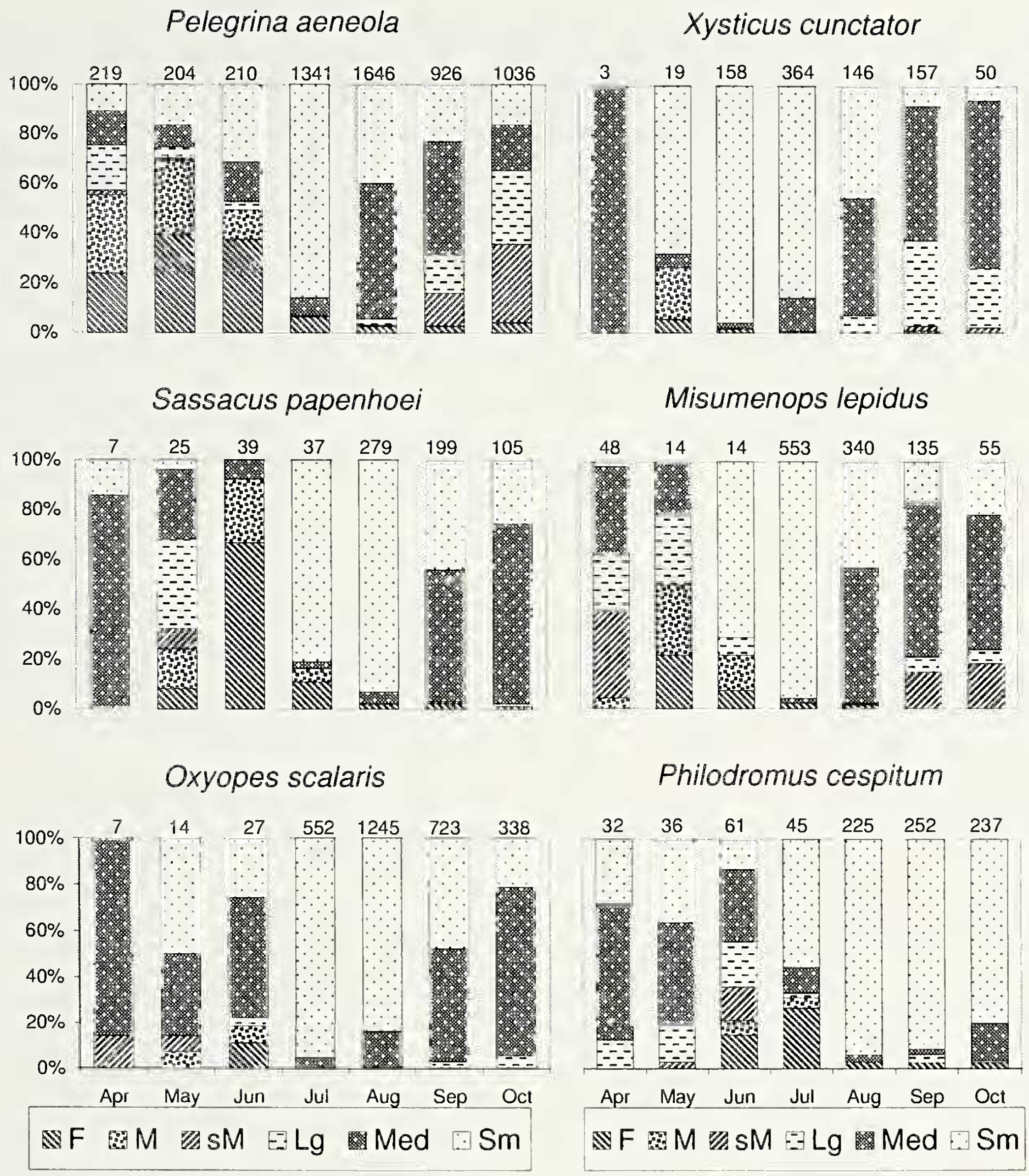

Figure 1.—Percentage of adults and different sized immatures of six common spider species found by month in combined beating tray and sweep net collections. F = female; M = male; sM = penultimate male; Lg = large immature; Med = medium sized immature; Sm = small immature. Number at the top of the column is the total number of specimens taken for the month.

sac was found among a group of ripening pears on 19 August 1998, and a female with a hatched egg mass was found in a codling moth pheromone trap on 29 October 1996. Three small immatures collected on 26 September 2003 yielded a recognizable *P. comatus* after two molts, a male after five molts, and a penultimate female after six molts. *Phidippus clarus* Keyserling 1885 also appears to mature during the summer (Table 2). *Phidippus audax* (Hentz 1845) appears to mature in the spring. Specimens from overwintering shelters (Table 1) were mostly medium and large immatures and, of the 42 individuals that overwintered in apple bins, 26 were penultimate females and 12 were penultimate males. *Phidippus johnsoni* (Peckham & Peckham 1883) also appears to mature in the spring. Overwintering and seasonal collection data for other Salticidae is summarized in Tables 1 and 2 respectively.

Oxyopidae.—*Oxyopes scalaris* Hentz 1845 was infrequently collected from March to June, but its numbers increased substantially in July and August. Medium-sized immatures made up 50% of the population in September and 73% in October, but large immatures were present in only small numbers both months. Miscellaneous collections included 2 females, 2 penultimate females, and 1 antepenultimate female on 26 May 2000; 1 female and 1 penultimate female on 30 May 2000; and 1 penultimate male on 1 June 2000. *Oxyopes scalaris* appears to mature in the spring and early summer and to be univoltine in the study area.

Thomisidae.—Immature *Xysticus cunctator* Thorell 1877 were commonly taken in the beat tray samples. Adults, however, were rare in the trees (one female out of 609 specimens) but were more frequently swept from the understory vegetation (five males and four females out of 288 specimens). Adults were most numerous in May according to sweep net and beat tray collections, but hand collected adults of both sexes were taken in April. New generation

Table 1.—Summary of spider overwintering stages: sm., med., lg. = small, medium, and large immatures (large immatures included antepenultimates of both sexes and penultimate females); sM = penultimate males; M = adult male; F = adult female. Additional observations: one med. *P. cespitum* molted three times to an adult female; the sm. *P. insperatus* molted four times to a male and seven of the med.'s molted three times each yielding five males and two females; one sM *P. alascensis* was reared to the adult stage.

Spider species	Overwintering stage					
	sm.	med.	lg.	sM	M	F
Salticidae						
Pelegrina aeneola (Curtis 1892)	39	87	227	192	1	1
Sassacus papenhoei Peckham & Peckham 1895	5	5				
Sassacus vitis (Cockerell 1894)	4	3			1	
Phidippus audax (Hentz 1845)	1	10	12	4		
Phanias watonus (Chamberlin & Ivie 1941)	21	49	23	4	10	28
Salticus scenicus (Clerck 1757)	5	24	34	46		1
Oxyopidae						
Oxyopes scalaris Hentz 1845		2				
Thomisidae						
Xysticus cunctator Thorell 1877		1				
Misumenops lepidus (Thorell 1877)	29	48	5	34		
Philodromidae						
Philodromus cespitum (Walckenaer 1802)	310	83	10	1		
Philodromus insperatus Schick 1965	1	9				
Philodromus californicus Keyserling 1884		9	129	1		
Philodromus rufus Walckenaer 1826		25	269	7		
Philodromus speciosus Gertsch 1934		2	10	1	3	5
Philodromus alascensis Keyserling 1884			1	2		
Tibellus oblongus (Walckenaer 1802)	27	16	4			
Ebo pepinensis Gertsch 1933	3	3	2			
Clubionidae						
Cheiracanthium mildei L. Koch 1864	104	210	37	40		
Cheiracanthium inclusum Hentz 1847		1		1		
Corinnidae						
Phrurotimpus borealis Emerton 1911		14	203	140		
Anyphaenidae						
Anyphaena pacifica (Banks 1896)	2	6	6			
Theridiidae						
Steatoda hespera Chamberlin & Ivie 1933	15	31	4	1	3	2
Linyphiidae						
Meioneta fillmorana (Chamberlin 1919)						1
Erigone spp.					1	
Pityohyphantes minidoka Chamberlin & Ivie 1943	11	19	3	1		1
Tetragnathidae						
Tetragnatha laboriosa Hentz 1850	6	1	1			
Dictynidae						
Dictyna coloradensis Chamberlin 1919			35	21	1	

spiderlings appeared in May and remained abundant through August (Fig. 1). Antepenultimate males, as indicated by rearing, were present as early as July. Penultimate females (reared individuals) and penultimate males (Fig. 1) were present by September. Larger immatures, including penultimates of both sexes, would therefore be the primary overwintering stages. This species appears to have an annual life cycle in the study area.

The phenology of *Misumenops lepidus* (Thorell 1877) was similar to that of *X. cunctator* although new generation spiderlings did not appear in large numbers until July (Fig. 1), a few weeks later than in *X. cunctator*. Penultimate males first appeared in August and were abundant in September, October, and the following April. Penultimate males and other immature stages overwintered (Table 1). *Misumenops lepidus* appeared to have an annual life cycle.

Philodromidae.—The phenology of *Philodromus cespitum* (Walckenaer 1802) (Fig. 1) was similar to that of *X. cunctator* and *M. lepidus* but was shifted later into the season. Adult females were most common in June and July, and small spiderlings, which could be found in all months, were most abundant from August to October. Five females with egg sacs

Table 2.—Summary by month of beating tray, sweep net, and hand collections of less common spider species: numbers of penultimate males, males, and females, respectively, are given. Additional observations: Penultimate female *E. militaris* were collected in April, May, September, and October; two antepenultimate female *X. gulosus* collected in July, one female collected in December; one penultimate female *P. insperatus* collected in June, one female collected in June laid three egg clutches in the lab; one antepenultimate female *P. californicus* collected in April, one antepenultimate female and 26 other large immatures collected in October; three antepenultimate male *A. trifasciata* collected in July and one in August, 2 penultimate females collected in August.

Spider species	April	May	June	July	Aug	Sept	Oct
Salticidae							
Eris militaris (Hentz 1845)	0-2-0	2-2-11	0-0-4	1-0-4	3-0-1	0-1-0	1-3-0
Phanias watonus (Chamberlin & Ivie 1941)				0-0-2			
Phidippus audax (Hentz 1845)		0-1-0	0-0-1	0-1-1	0-0-1		10-0-1
Phidippus clarus Keyserling 1885				1-7-11	0-1-1	0-0-3	0-0-1
Phidippus comatus Peckham & Peckham 1901		1-0-0	9-1-1	1-11-8	0-4-4	0-1-0	0-0-1
Phidippus johnsoni Peckham & Peckham 1883	0-3-2			1-0-0		1-0-0	2-1-0
Sassacus vitis (Cockerell 1894)					0-2-0		
Salticus scenicus (Clerck 1757)		1-0-0	0-1-1				
Thomisidae							
Xysticus gulosus Keyserling 1880				1-0-0		0-0-1	0-1-3
Philodromidae							
Philodromus insperatus Schick 1965		2-0-0	0-2-2	0-0-4			
Philodromus californicus Keyserling 1884							3-0-0
Philodromus rufus Walekenaer 1826		0-2-0					
Tibellus oblongus (Walckenaer 1802)		0-1-2	0-0-1	1-9-9	1-1-7	0-0-1	
Tibellus asiaticus Kulczyn'ski 1908				0-0-1			
Clubionidae							
Cheiracanthium inclusum Hentz 1847		2-1-0			0-0-1		
Corinnidae							
Castianeira longipalpa Hentz 1847				1-0-0			
Anyphaenidae							
Anyphaena pacifica (Banks 1896)			0-0-1	0-0-1		3-0-0	
Linyphiidae							
Spirembolus mundus Chamberlin & Ivie 1933			7-0-0	14-0-0	11-0-0	1-1-0	0-1-0
Tenuiphantes tenuis (Blackwall 1852)	0-0-1		0-2-2	0-0-1	0-0-2	0-1-1	0-1-0
Collinsia ksenius (Crosby & Bishop 1928)	0-0-1		0-5-3	0-3-1			0-1-3
Walckenaeria subspiralis Millidge 1983			0-5-0	0-1-0		0-1-0	0-2-4
Pityohyphantes minidoka Chamberlin & Ivie 1943		0-1-0					
Tetragnathidae							
Tetragnatha laboriosa Hentz 1850		5-4-2		0-2-2	4-14-11	1-0-3	1-0-2
Tetragnatha versicolor Walckenaer 1841		0-2-0		0-1-1			
Araneidae							
Argiope trifasciata (Forsskål 1775)				1-0-0	3-1-0	0-0-2	

were collected in July, and a female with an egg sac containing undispersed spiderlings was found in September. Small and medium sized immatures most commonly overwintered (Table 1), and an annual life cycle in the study area is indicated.

Tibellus oblongus (Walckenaer 1802) occurred in many orchards. While primarily an inhabitant of the understory vegetation (212 of 256 specimens), individuals were occasionally found in the trees. It overwintered as immatures of various sizes (Table 1) and is probably univoltine in the study area. Overwintering and seasonal collection data for less common species in the Philodromidae are given in Tables 1 and 2 respectively.

Clubionidae.—*Cheiracanthium mildei* L. Koch 1864 occurred in many study orchards and appears to have an annual life cycle in the study area. Collection data for the species are summarized in Table 3. All sizes of *C. mildei* immatures overwintered including penultimate males and females (Table 1). *Cheiracanthium inclusum* Hentz 1847 was collected in only one of our study orchards but appears to have a phenology similar to that of *C. mildei*. Small immatures were most abundant in July (15 specimens) and August (20), medium-sized immatures were most abundant in September (19) and October (17), and large immatures were most abundant in October (13).

Theridiidae.—*Theridion neomexicanum* Banks 1901 was a common, primarily arboreal species that is clearly univoltine in the study area (Fig. 2). Males were first noted in May, but both sexes were most abundant in June and July. A male and a penultimate female were found together in a web on an apple leaf on 11 June 1998, females with egg sacs were collected on apple leaves on 10 July 1998 and 27 July 1999, and a female

Table 3.—Seasonal occurrence of *Cheiracanthium mildei* based on combined beat tray, sweep net, and hand collections. Spider stages: small, medium, large = small, medium, and large immatures (large immatures included antepenultimate nymphs of both sexes and penultimate females); sM = penultimate males. Additional observations: two of the July and one of the September females were guarding egg sacs.

Month of collection	Developmental stage					
	small	medium	large	sM	Male	Female
May	1			1	1	
June		1	1			1
July	28	5	3		1	3
August	29	28	2			
September	18	29	14	5		3
October	19	44	23	10		

with a vacated egg sac was found on 6 August 1999. Penultimate males were not observed by October, and overwintering must therefore occur as immatures smaller than penultimates in undetermined locations.

Linyphiidae.—*Meioneta fillmorana* (Chamberlin 1919) is also primarily an arboreal spider. Its numbers peaked in May, after which there was a four month decline and then a marked rebound in October. Such a late season increase was unusual for spiders in this study especially since the October population of *M. fillmorana* consisted entirely of adults (Fig. 2). Six years of beat tray samples all showed a similar pattern, however. The species appears to be univoltine. Although we obtained virtually no overwintering data for *M. fillmorana*, it seems reasonable to infer, given the preponderance of females in the October collections, that overwintering probably takes place in the egg stage.

At least two species of *Erigone* occurred in the orchards: *Erigone dentosa* O. Pickard-Cambridge 1894 and *Erigone aletris* Crosby & Bishop 1928. We were unable to separate the two species with certainty. Adults of both sexes were present from at least May to October and were most abundant in October and June (Table 4). Although *Erigone* were well represented in the trees, sweep samples for 1996 and 1997 yielded a majority (65%) of the specimens that were collected. *Erigone* is also common on the ground based on pitfall trap collections (Miliczky et al. 2000), and thus has a broad distribution among habitats within the orchard. Tables 1 and 2 have data for less common Linyphiidae.

Other families.—Data for less commonly collected spiders in other families is summarized in Tables 1 and 2. Included in this group: *Anyphaena pacifica* (Banks 1896) (Anyphaenidae) was occasionally found in the trees and immatures utilized overwintering shelters; *Tetragnatha laboriosa* Hentz 1850 (Tetragnathidae) was commonly swept from understory vegetation, and immatures were taken with some regularity in late season beat trays; *Dictyna coloradensis* Chamberlin 1919 (Dictynidae) was common only at the USDA research farm where it constructed webs on apple and pear leaves and tall weeds in adjacent uncultivated ground.

DISCUSSION

Many temperate zone spiders have a single generation per year (Gertsch 1979; Foelix 1996), and this appeared to be true of Washington species for which sufficient data were obtained. Within the broad latitudinal range of the temperate zone, however, factors that may influence spider development vary widely, and other life history patterns have been documented. About half of the 52 species studied in Denmark by Toft (1976, 1978) were biennial, and Almquist (1969) found a similar proportion of biennial species among 20 studied in Sweden. Almquist (1969) also observed that in Sweden the life cycles of some species were twice as long as the life cycles of the same or related species in southwestern Europe. Similarly, *Philodromus cespitum* is biennial in Nova Scotia (Dondale 1961) but univoltine farther to the south in Ontario (Putman 1967).

In North America and Denmark maturation times among univoltine spiders form a continuum from the spring to the fall (Toft 1976; Gertsch 1979). Some litter inhabiting species of Linyphiidae mature and reproduce even during the winter months (Duffey 1956; Schaefer 1977). Washington species for which we acquired sufficient data appeared to have well-defined periods of reproduction (stenochrony) and could be classified as stenoehronous with reproduction in spring and summer (Schaefer 1977).

We noted that at a given time during the season, and also in the overwintering shelters, some species were represented by several developmental stages, whereas others were represented by only a few. Small, medium, and large immature *Pelegrina aeneola* could be found during much of the season (Fig. 1) and all these stages also overwintered (Table 1). *Cheiracanthium mildei* showed a similarly broad range of overwintering stages, while *Phanias watonus* was even more extreme as adults of both sexes also commonly overwintered (Table 1). In contrast, small immature *Philodromus cespitum* dominated the orchard collections from August to October (Fig. 1) and was the principal overwintering stage (Table 1). *Philodromus californicus* and *Dictyna coloradensis* spent the winter primarily as large immatures and/or penultimate males and penultimate females (Table 1). Factors tending to increase the length of time during the season when a given developmental stage is present include long-lived females that remain with an egg sac until the young disperse and produce more than one clutch of eggs. Egg sac guarding by *P. aeneola* was observed in the field, egg sacs were found as late as September, and females are capable of producing a second clutch of eggs. *Pelegrina galatea* (Walckenaer 1837) also guarded its eggs and produced multiple clutches in the laboratory (Horner & Starks 1972). We observed female *C. mildei* guarding eggs in the field and multiple clutches of eggs were produced under laboratory conditions (Mansour et al. 1980b).

A number of the more common orchard spiders were poorly or not at all represented in overwintering shelters and presumably seek alternative sites inside or outside the orchard. Pekar (1999c) noted a similar phenomenon. *Oxyopes scalaris*, the only member of the family that occurs in Washington (Crawford 1988), presented an interesting case. Large numbers of small immature *O. scalaris* appeared in the orchards rather abruptly in July, and size increase in the population was observed as the season progressed. Large immatures and adults were rare in orchard collections (Fig. 1), however, and only two immatures were found in overwintering shelters (Table 1). The fate of the medium sized immatures that are so

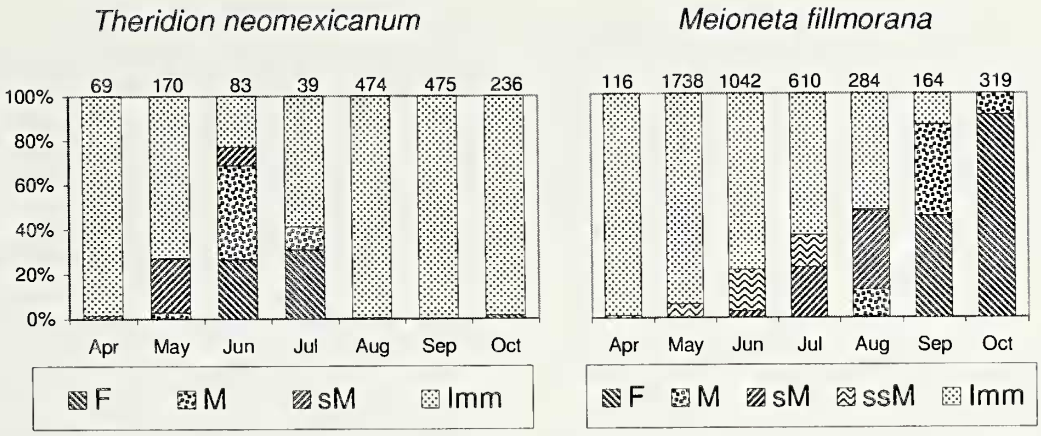

Figure 2.—Percentage of adults and immatures of two common spider species found by month in combined beating tray and sweep net collections. F = female; M = male; sM = penultimate male; ssM = antepenultimate male (*M. fillmorana* only); Imm – all other immature stages. Number at the top of the column is the total number of specimens taken for the month.

common in the orehards in October remains to be determined. The opposite situation was noted in *Steatoda hespera* which utilized overwintering shelters but was not taken by beating tray or sweep net. Like most members of the genus, *S. hespera* webs are probably situated in rock and bark crevices and in cavities near the ground (Levi 1957) and would not have been sampled. Horton et al. (2001) changed a portion of their cardboard bands on pear and apple trees weekly from August to December. They determined that several species utilized the bands as temporary refuges during the autumn but overwintered elsewhere.

Despite their abundance in terrestrial habitats and their exclusively predatory habits, Debach & Rosen (1991) noted a general neglect of spiders as potential biological control agents and attributed this, in part, to their generalist predatory habits. Other authors, noting the diversity of prey capture strategies and microhabitat exploitation patterns of spiders, have emphasized the contribution of the spider community as a whole to insect control in agroecosystems (Reichert & Lockley 1984; Marc & Canard 1997). Interest in the composition of spider faunas in orchards began over 50 years ago and appears to have increased given the number of studies conducted in recent years. However, studies attempting to evaluate the importance of spider predation on orchard pests are few (e.g., MacLellan 1973; Mansour et al. 1980a; Amalin et al. 2001; Miliczky & Calkins 2002).

Table 4.—Summary by month of combined beating tray and sweep net collections of *Erigone* spp. Spider stages: ssM = antepenultimate male; sM = penultimate male.

Month of collection	Developmental stage			
	ssM	sM	Male	Female
April	4			1
May	40	28	4	6
June	19	59	71	53
July	49	68	23	14
August	24	35	23	14
September	43	50	34	22
October	2	32	192	197

During this study we observed most of the common orchard spiders feeding on pests. *Pelegrina aeneola*, *O. scalaris*, *P. cespitum*, *X. cunctator*, and *M. lepidus* all used a variety of smaller pest species as prey, including leafhoppers, leafminers, aphids, thrips, and mites. The webs of *M. fillmorana* snared aphids and thrips as well as tiny flies and parasitoid wasps. The large salticid *Phidippus clarus* took prey up to the size of an adult earwig. Some of the orchard spiders or a close relative may be important predators in agroecosystems more generally. *Pelegrina aeneola* and other members of the genus may be important in biological control because they are often abundant and are known to feed on pest insects (Horner 1972; Jennings & Houseweart 1978; Mason & Paul 1988). *Oxyopes salticus* Hentz 1845, a close relative of *O. scalaris*, is a dominant predator in row crops in the United States and an important predator of pest insects (Young & Lockley 1985). *Cheiracanthium mildei* was described by Wise (1993) as a potentially important biological control agent in a number of agroecosystems. Mansour et al. (1980a) determined that *C. mildei* was the most effective spider predator of a lepidopteran pest of apples in Israel. Miliczky & Calkins (2002) rated it as having the greatest potential as a predator of pest leafrollers in Washington orchards out of 11 species tested.

The role of spiders in orchard pest control is of considerable interest given the current trend toward reduced use of broad spectrum insecticides, the large numbers of spiders often observed when pesticide use is decreased or eliminated, and the great diversity among orchard-inhabiting spiders in size, behavior, and prey-capture strategies. All of these factors suggest that spiders should have substantial potential for contributing to orchard pest control. Future studies should further document the importance of this interesting but often overlooked group of beneficial organisms in controlling pest species in orchards and other agricultural systems.

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